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NATIONAL EUTROPHICATION SURVEY

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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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REPORT
ON
PACTOLA RESERVOIR
PENNINGTON COUNTY
SOUTH DAKOTA
EPA REGION VIII
WORKING PAPER No. 617

WITH THE COOPERATION OF THE

SOUTH DAKOTA DEPARTMENT OF ENVIRONMENTAL PROTECTION

AND THE

SOUTH DAKOTA NATIONAL GUARD

DECEMBER, 1976

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's freshwater lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the South Dakota Departments of Environmental Protection and Game, Fish and Parks for professional involvement, to the South Dakota National Guard for conducting the tributary sampling phase of the Survey, and to those wastewater treatment plant operators who voluntarily provided effluent samples.

Allyn Lockner, Secretary, and Blaine Barker and Duane Murphy, Department of Environmental Quality; Douglas Hansen, Department of Game, Fish and Parks; and James Hayden, Director, State Lakes Preservation Committee provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

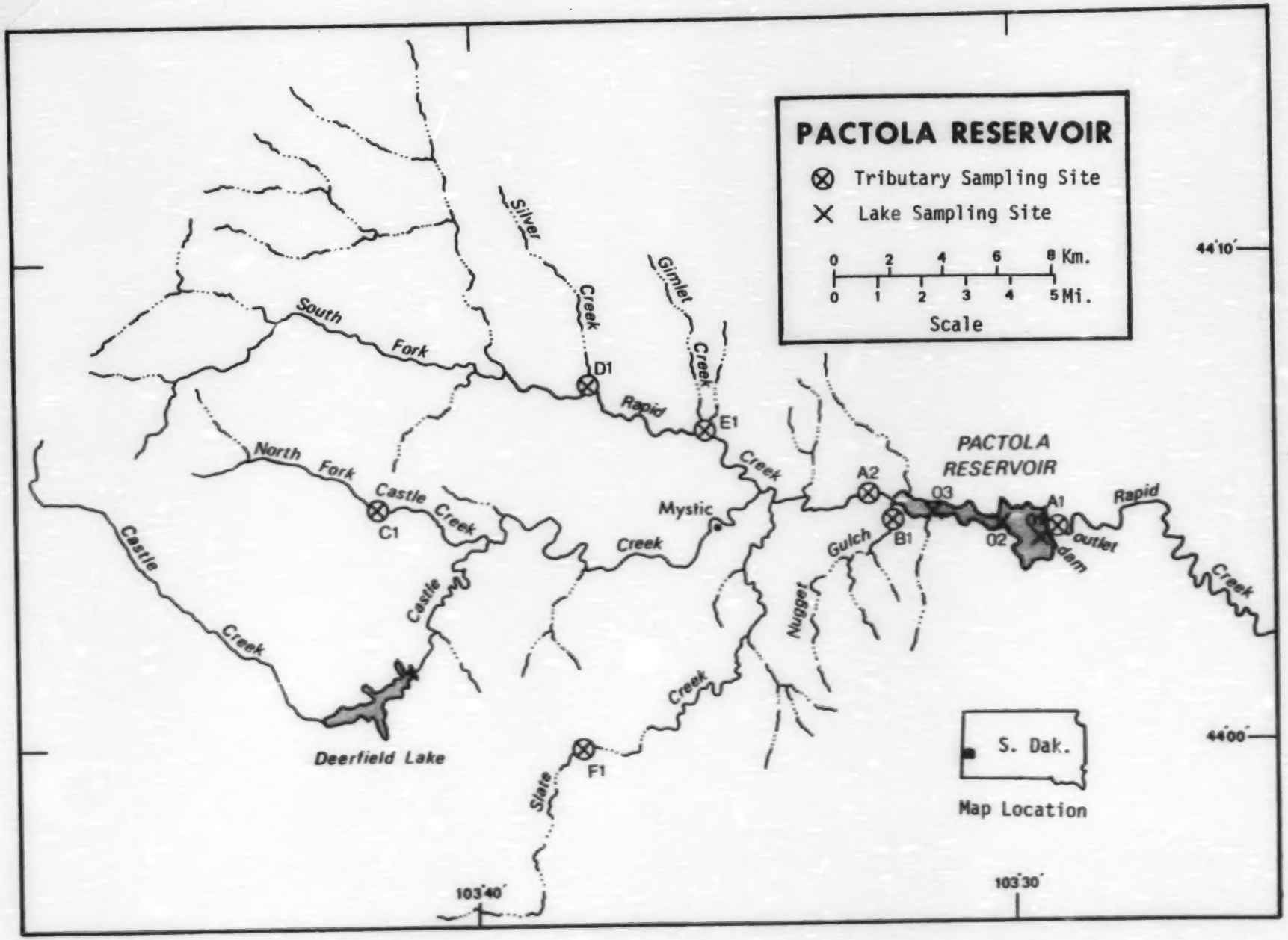
Major General Duane L. Corning, the Adjutant General of South Dakota, and Project Officer Colonel Robert D. Chalberg, who directed the volunteer efforts of the South Dakota National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF SOUTH DAKOTA

LAKE NAME	COUNTY
Albert	Kingsbury
Alvin	Lincoln
Angostura	Fall River
Brant	Lake
Byron	Beadle
Clear	Marshall
Clear	Minnehaha
Cochrane	Deuel
Cottonwood	Spink
Deerfield	Pennington
Enemy Swim	Day
Herman	Lake
John	Hamlin
Kampeska	Codington
Madison	Lake
Mitchell	Davidson
Norden	Hamlin
East Oakwood	Brookings
West Oakwood	Brookings
Pactola	Pennington
Pickerel	Day
Poinsett	Brookings, Lake
Red Iron South	Marshall
Richmond	Brown
Roy	Marshall
Sand	Brown
Sheridan	Pennington
Stockdale	Custer
East Vermillion	McCook
Wall	Minnehaha
Waubay	Day


PACTOLA RESERVOIR
Tributary Sampling Site
Lake Sampling Site
0 2 4 6 8 Km.
0 1 2 3 4 5 Mi.
Scale
44°10'
44°00'
103°40'
103°30'
South Fork
North Fork
Castle Creek
Silver Creek
Gimlet Creek
Rapid Creek
Mystic Creek
Nugget Gulch
Slate Creek
Rapid Creek
outlet dam
PACTOLA RESERVOIR
Deerfield Lake
D1
E1
C1
A2
B1
O3
O2
A1
F1
S. Dak.
Map Location

PACTOLA RESERVOIR

STORET NO. 4620

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Pactola Reservoir is oligotrophic. It ranked first in overall trophic quality when the 31 South Dakota lakes sampled in 1974 were compared using a combination of six water quality parameters*. None of the other lakes had less median total phosphorus, one had less median dissolved orthophosphorus, none had less median inorganic nitrogen (one had the same) or mean chlorophyll a, and none of the others had greater mean Secchi disc transparency. No significant depression of dissolved oxygen occurred at depths as great as 39.6 meters.

Survey limnologists did not observe any nuisance conditions during sampling visits and commented on the attractive appearance of the reservoir.

B. Rate-Limiting Nutrient:

The algal assay results are not considered representative of conditions in the reservoir at the times the samples were taken. The reservoir data indicate phosphorus limitation in April and nitrogen limitation in July and September.

C. Nutrient Controllability:

1. Point sources--The only point sources which may have con-

* See Appendix A.

tributed to the total phosphorus load during the sampling year were septic tanks at Silver City which were estimated to have contributed 0.6% of the total load. However, additional investigation would be needed to determine the significance of such sources.

The present phosphorus loading of 1.17 $g/m^2/year$ is more than that proposed by Vollenweider (Vollenweider and Dillon, 1974) as a eutrophic loading (see page 10). If this loading continues, progressive signs of eutrophication are likely to become evident.

2. Non-point sources--Non-point sources contributed 99.4% of the total phosphorus input to Pactola Reservoir during the sampling year. Rapid Creek contributed 89.5% and the ungaged minor tributaries and immediate drainage contributed an estimated 8.4% of the total.

Any reduction of the non-point source phosphorus load probably would be difficult since the surrounding terrian is mostly forested. Additional investigation is needed to determine the contribution and controllability of phosphorus resulting from land-use practices in the drainage basin.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS†

A. Lake Morphometry††:

1. Surface area: 3.48 kilometers^2.
2. Mean depth: 16.4 meters.
3. Maximum depth: 42.7 meters.
4. Volume: 57.148 x 10^6 m^3.
5. Mean hydraulic retention time: 1.6 years.

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

Name	Drainage area (km^2)*	Mean flow (m^3/sec)*
Rapid Creek	756.3	1.130
Minor tributaries & immediate drainage -	69.0	0.012
Totals	825.3	1.142

2. Outlet -

Rapid Creek	828.8**	1.100

C. Precipitation***:

1. Year of sampling: 67.1 centimeters.
2. Mean annual: 70.4 centimeters.

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† Table of metric conversions--Appendix B.
†† Surface area and maximum depth - Murphey, 1974; volume - Anonymous, 1976.
* For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".
** Includes area of lake.
*** See Working Paper No. 175.

III. LAKE WATER QUALITY SUMMARY

Pactola Reservoir was sampled three times during the open-water season of 1974 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from a number of depths at three stations on the reservoir (see map, page v). During each visit, a single depth-integrated (4.6 m to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the April and September visits, single 18.9-liter depth-integrated samples were composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 39.6 meters at station 1, 24.4 meters at station 2, and 7.6 meters at station 3.

The sampling results are presented in full in Appendix D and are summarized in the following table.

A. SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS FOR PACTOLA RESERVOIR
STORET CODE 4620

PARAMETER	1ST SAMPLING (4/25/74) 3 SITES RANGE	MEAN	MEDIAN	2ND SAMPLING (7/15/74) 3 SITES RANGE	MEAN	MEDIAN	3RD SAMPLING (9/12/74) 3 SITES RANGE	MEAN	MEDIAN
TEMP (C)	5.0 - 8.0	6.3	6.4	6.0 - 22.0	16.8	20.8	7.3 - 16.3	13.7	15.6
DISS OXY (MG/L)	8.6 - 10.4	10.0	10.2	6.4 - 9.2	7.6	7.4	4.0 - 9.0	7.5	8.0
CNDCTVY (MCROMO)	220. - 250.	230.	230.	250. - 373.	324.	350.	230. - 295.	275.	288.
PH (STAND UNITS)	****** -**********			8.0 - 8.6	8.3	8.3	7.4 - 8.3	8.0	8.1
TOT ALK (MG/L)	146. - 166.	150.	148.	123. - 167.	158.	160.	156. - 194.	166.	165.
TOT P (MG/L)	0.007 - 0.059	0.013	0.009	0.050 - 0.082	0.062	0.060	0.007 - 0.020	0.010	0.009
ORTHO P (MG/L)	0.002 - 0.010	0.005	0.004	0.003 - 0.072	0.046	0.051	0.002 - 0.009	0.006	0.006
NO2+NO3 (MG/L)	0.030 - 0.110	0.054	0.050	0.020 - 0.090	0.054	0.060	0.020 - 0.140	0.031	0.020
AMMONIA (MG/L)	0.020 - 0.040	0.028	0.030	0.030 - 0.100	0.051	0.050	0.020 - 0.040	0.024	0.020
KJEL N (MG/L)	0.200 - 0.300	0.213	0.200	0.200 - 0.500	0.235	0.200	0.200 - 0.500	0.245	0.200
INORG N (MG/L)	0.050 - 0.150	0.082	0.070	0.060 - 0.190	0.105	0.110	0.040 - 0.180	0.055	0.040
TOTAL N (MG/L)	0.230 - 0.370	0.267	0.250	0.220 - 0.580	0.289	0.260	0.220 - 0.640	0.276	0.220
CHLRPYL A (UG/L)	1.9 - 2.2	2.0	1.9	1.3 - 2.2	1.8	2.0	0.6 - 0.6	0.6	0.6
SECCHI (METERS)	2.7 - 7.9	6.0	7.3	4.0 - 7.6	6.3	7.3	3.4 - 8.6	6.9	8.6

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
04/25/74	1. *Chroomonas sp.*	291
	2. *Fragilaria sp.*	194
	3. *Ankistrodesmus sp.*	97
	4. *Gymnodinium sp.*	49
	Total	631
07/15/74	1. *Chroomonas sp.*	242
	2. *Asterionella sp.*	81
	3. *Cryptomonas sp.*	40
	4. *Stephanodiscus sp.*	40
	Total	403
09/12/74	1. *Chroomonas sp.*	547
	2. *Microcystis sp.*	96
	3. *Cryptomonas sp.*	49
	4. *Euglena sp.*	24
	5. *Asterionella sp.*	24
	Other genera	21
	Total	761

2. Chlorophyll *a* -

Sampling Date	Station Number	Chlorophyll *a* (µg/l)
04/25/74	1	2.2
	2	1.9
	3	1.9
07/15/74	1	2.0
	2	1.3
	3	2.2
09/12/74	1	0.6
	2	0.6
	3	0.6

C. Limiting Nutrient Study:

The algal assay results are not considered representative of conditions in the reservoir at the times the samples were collected (04/25/74 and 09/12/74) due to significant nutrient losses in the samples during shipment from the field to the laboratory.

The reservoir data indicate that phosphorus was limiting in April; i.e., the mean inorganic nitrogen/orthophosphorus ratios were 17/1 or greater at all stations. However, nitrogen limitation is indicated in July and September; the mean N/P ratios were 11/1 or less at all stations, and nitrogen limitation would be expected.

IV. NUTRIENT LOADINGS
(See Appendix E for data)

For the determination of nutrient loadings, the South Dakota National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the high runoff months of April and June when two samples were collected at one of the sites. Sampling was begun in October, 1974, in September, 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the South Dakota District Office of the U.S. Geological Survey for the tributary sites nearest the reservoir.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*.

Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the nutrient loads at station A-2, in $kg/km^2/year$, and multiplying by the ZZ area in km^2.

A. Waste Sources:

1. Known municipal - None
2. Known industrial - None

* See Working Paper No. 175.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/ yr	% of total
a. Tributaries (non-point load) -		
Rapid Creek	3,655	89.5
b. Minor tributaries & immediate drainage (non-point load) -	345	8.4
c. Known municipal STP's - None	-	-
d. Septic tanks* -	25	0.6
e. Known industrial - None	-	-
f. Direct precipitation** -	60	1.5
Total	4,085	100.0

2. Outputs -

Lake outlet - Rapid Creek 455

3. Net annual P accumulation - 3,630 kg.

* Estimate based on 51 dwellings at Silver City; see Working Paper No. 175.
** See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/ yr	% of total
a. Tributaries (non-point load) -		
Rapid Creek	32,020	81.0
b. Minor tributaries & immediate drainage (non-point load) -	2,900	7.3
c. Known municipal STP's - None	-	-
d. Septic tanks* -	870	2.2
e. Known industrial - None	-	-
f. Direct precipitation** -	3,755	9.5
Total	39,545	100.0

2. Outputs -

Lake outlet - Rapid Creek 22,345

3. Net annual N accumulation - 17,200 kg.

D. Non-point Nutrient Export by Subdrainage Area:

Tributary	kg $P/km^2/yr$	kg $N/km^2/yr$
Rapid Creek	5	42

E. Mean Nutrient Concentrations in Ungaged Streams:

Tributary	Mean Total P Conc. (mg/l)	Mean Total N Conc. (mg/l)
N. Fork Castle Creek	0.031	0.614
Silver Creek	0.012	0.452
Gimlet Creek	0.022	0.518
Slate Creek	0.032	0.498

* Estimate based on 51 dwellings at Silver City; see Working Paper No. 175.
** See Working Paper No. 175.

F. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m^2/yr	1.17	1.04	11.4	4.9

Vollenweider phosphorus loadings ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Pactola Reservoir:

"Dangerous" (eutrophic loading)	0.62
"Permissible" (oligotrophic loading)	0.31

V. LITERATURE REVIEWED

Anonymous, 1976. Water resources data for South Dakota, water year 1975. Water Data Report SD-75-1, U.S.G.S., Huron.

Murphey, Duane G., 1974. Personal communication (reservoir information and morphometry). SD Dept. of Env. Prot., Pierre.

Vollenweider, R. A., and P. J. Dillon, 1974. The application of the phosphorus loading concept to eutrophication research. Natl. Res. Council of Canada Publ. No. 13690, Canada Centre for Inland Waters, Burlington, Ontario.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P
4601	LAKE ALBERT	0.321	0.170	489.111	106.289	9.200	0.019
4602	ALVIN LAKE	0.067	0.970	442.833	4.700	9.400	0.017
4603	ANGOSTURA RESERVOIR	0.019	0.160	423.333	3.717	13.000	0.005
4604	BRANT LAKE	0.194	0.130	432.833	34.150	11.800	0.113
4605	LAKE BYRON	0.443	0.370	488.333	149.350	9.000	0.146
4606	CLEAR LAKE	0.027	0.075	430.167	11.983	8.800	0.009
4607	CLEAR LAKE	1.400	0.270	495.333	691.000	7.000	0.468
4608	COCHRANE LAKE	0.037	0.150	446.000	15.683	15.000	0.008
4609	COTTONWOOD LAKE	0.685	0.265	490.333	112.017	8.600	0.417
4610	DEERFIELD RESERVOIR	0.033	0.080	303.333	3.650	15.000	0.022
4611	ENEMY SWIM LAKE	0.037	0.085	442.600	14.200	8.200	0.013
4612	LAKE HERMAN	0.340	0.155	485.000	58.733	8.600	0.174
4613	ST JOHN LAKE	0.349	0.080	489.400	120.880	9.800	0.025
4614	LAKE KAMPESKA	0.220	0.105	468.889	20.567	8.200	0.128
4615	MADISON LAKE	0.259	0.090	445.555	22.578	14.000	0.107
4616	LAKE MITCHELL	0.099	0.085	465.833	14.883	13.800	0.015
4617	LAKE NORDEN	0.256	0.165	488.667	46.800	10.000	0.050
4618	OAKWOOD LAKE EAST	0.146	0.175	487.000	113.600	10.000	0.009
4619	OAKWOOD LAKE WEST	0.181	0.135	485.833	159.667	9.600	0.021
4620	PACTOLA RESERVOIR	0.011	0.070	248.444	1.478	11.000	0.006
4621	PICKEREL LAKE	0.049	0.095	439.833	15.833	9.600	0.009
4622	LAKE POINSETT	0.115	0.315	468.444	40.211	10.000	0.023
4623	LAKE RED IRON SOUTH	0.042	0.110	430.333	6.883	7.600	0.010
4624	RICHMOND LAKE	0.187	0.150	410.000	18.467	10.000	0.144
4625	ROY LAKE	0.034	0.070	431.000	13.333	11.000	0.010
4626	SAND LAKE	0.489	0.110	471.800	65.790	12.800	0.288
4627	SHERIDAN LAKE	0.053	0.105	394.000	15.433	15.000	0.016
28	STOCKADE LAKE	0.233	0.150	432.000	25.400	15.000	0.109

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P
4629	LAKE VERMILLION	0.211	0.100	472.833	100.800	9.200	0.092
4630	WALL LAKE	0.194	0.160	441.667	55.267	7.400	0.076
4631	WAUBAY LAKE NORTH	0.098	0.145	469.555	127.033	11.400	0.023

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P	INDEX NO
4601	LAKE ALBERT	20 (6)	20 (6)	10 (3)	23 (7)	68 (20)	60 (18)	201
4602	ALVIN LAKE	67 (20)	0 (0)	57 (17)	90 (27)	63 (19)	63 (19)	340
4603	ANGOSTURA RESERVOIR	97 (29)	30 (9)	87 (26)	93 (28)	20 (6)	100 (30)	427
4604	BRANT LAKE	40 (12)	53 (16)	70 (21)	47 (14)	27 (8)	23 (7)	260
4605	LAKE BYRON	10 (3)	3 (1)	17 (5)	7 (2)	73 (22)	13 (4)	123
4606	CLEAR LAKE	93 (28)	93 (28)	83 (25)	83 (25)	77 (23)	90 (27)	519
4607	CLEAR LAKE	0 (0)	10 (3)	0 (0)	0 (0)	100 (30)	0 (0)	110
4608	COCHRANE LAKE	83 (25)	40 (11)	50 (15)	67 (20)	5 (0)	93 (28)	338
4609	COTTONWOOD LAKE	3 (1)	13 (4)	3 (1)	20 (6)	82 (24)	3 (1)	124
4610	DEERFIELD RESERVOIR	90 (27)	88 (26)	97 (29)	97 (29)	5 (0)	53 (16)	430
4611	ENEMY SWIM LAKE	80 (24)	82 (24)	60 (18)	77 (23)	88 (26)	73 (22)	460
4612	LAKE HERMAN	17 (5)	33 (10)	27 (8)	33 (10)	82 (24)	10 (3)	202
4613	ST JOHN LAKE	13 (4)	88 (26)	7 (2)	13 (4)	53 (16)	43 (13)	217
4614	LAKE KAMPESKA	33 (10)	65 (19)	40 (12)	57 (17)	88 (26)	20 (6)	303
4615	MADISON LAKE	27 (8)	77 (23)	53 (16)	53 (16)	13 (4)	30 (9)	253
4616	LAKE MITCHELL	60 (18)	82 (24)	47 (14)	73 (22)	17 (5)	70 (21)	349
4617	LAKE NORDEN	23 (7)	23 (7)	13 (4)	40 (12)	45 (12)	40 (12)	184
4618	OAKWOOD LAKE EAST	53 (16)	17 (5)	20 (6)	17 (5)	45 (12)	85 (25)	237
4619	OAKWOOD LAKE WEST	50 (15)	50 (15)	23 (7)	3 (1)	58 (17)	57 (17)	241
4620	PACTOLA RESERVOIR	100 (30)	98 (29)	100 (30)	100 (30)	35 (10)	97 (29)	530
4621	PICKEREL LAKE	73 (22)	73 (22)	67 (20)	63 (19)	58 (17)	85 (25)	419
4622	LAKE POINSETT	57 (17)	7 (2)	43 (13)	43 (13)	45 (12)	47 (14)	242
4623	LAKE RED IRON SOUTH	77 (23)	58 (17)	80 (24)	87 (26)	93 (28)	78 (23)	473
4624	RICHMOND LAKE	47 (14)	40 (11)	90 (27)	60 (18)	45 (12)	17 (5)	299
4625	ROY LAKE	87 (26)	98 (29)	77 (23)	80 (24)	35 (10)	78 (23)	455
4626	SAND LAKE	7 (2)	58 (17)	33 (10)	30 (9)	23 (7)	7 (2)	158
4627	SHERIDAN LAKE	70 (21)	65 (19)	93 (28)	70 (21)	5 (0)	67 (20)	370
[illegible]	STOCKADE LAKE	30 (9)	40 (11)	73 (22)	50 (15)	5 (0)	27 (8)	225

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P	INDEX NO
4629	LAKE VERMILLION	37 (11)	70 (21)	30 (9)	27 (8)	68 (20)	33 (10)	265
4630	WALL LAKE	43 (13)	27 (8)	63 (19)	37 (11)	97 (29)	37 (11)	304
4631	WAUBAY LAKE NORTH	63 (19)	47 (14)	37 (11)	10 (3)	30 (9)	50 (15)	237

LAKES RANKED BY INDEX NOS.

RANK	LAKE CODE	LAKE NAME	INDEX NO
1	4620	PACTOLA RESERVOIR	530
2	4606	CLEAR LAKE	519
3	4623	LAKE RED IRON SOUTH	473
4	4611	ENEMY SWIM LAKE	460
5	4625	ROY LAKE	455
6	4610	DEERFIELD RESERVOIR	430
7	4603	ANGOSTURA RESERVOIR	427
8	4621	PICKEREL LAKE	419
9	4627	SHERIDAN LAKE	370
10	4616	LAKE MITCHELL	349
11	4602	ALVIN LAKE	340
12	4608	COCHRANE LAKE	338
13	4630	WALL LAKE	304
14	4614	LAKE KAMPESKA	303
15	4624	RICHMOND LAKE	299
16	4629	LAKE VERMILLION	265
17	4604	BRANT LAKE	260
18	4615	MADISON LAKE	253
19	4622	LAKE POINSETT	242
20	4619	OAKWOOD LAKE WEST	241
21	4631	WAUBAY LAKE NORTH	237
22	4618	OAKWOOD LAKE EAST	237
23	4628	STOCKADE LAKE	225
24	4613	ST JOHN LAKE	217
25	4612	LAKE HERMAN	202
26	4601	LAKE ALBERT	201
27	4617	LAKE NORDEN	184
28	4626	SAND LAKE	158

LAKES RANKED BY INDEX NOS.

RANK	LAKE CODE	LAKE NAME	INDEX NO
29	4609	COTTONWOOD LAKE	124
30	4605	LAKE BYRON	123
31	4607	CLEAR LAKE	110

APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR SOUTH DAKOTA 05/03/76

LAKE CODE 4620 PACTOLA RES.

TOTAL DRAINAGE AREA OF LAKE(SQ KM) 828.8

TRIBUTARY	SUB-DRAINAGE AREA(SQ KM)	NORMALIZED FLOWS(CMS) JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
4620A1	828.8	0.37	0.37	0.51	0.93	2.07	2.69	2.12	1.47	1.13	0.68	0.45	0.40	1.10
4620A2	756.3	0.45	0.48	0.74	1.39	2.12	2.75	1.61	1.19	1.10	0.76	0.51	0.45	1.13
4620ZZ	72.5	0.0	0.0	0.0	0.028	0.057	0.028	0.028	0.0	0.0	0.0	0.0	0.0	0.012

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 828.8 TOTAL FLOW IN = 13.71
SUM OF SUB-DRAINAGE AREAS = 828.8 TOTAL FLOW OUT = 13.20

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
4620A1	10	74	0.453	12	0.425				
	11	74	0.311	16	0.453				
	12	74	0.425	14	0.396				
	1	75	0.425	25	0.425				
	2	75	0.425	15	0.425				
	3	75	0.425	15	0.425				
	4	75	0.453	12	0.453				
	5	75	2.039	29	2.010				
	6	75	2.039	16	2.039				
	7	75	2.067	12	2.039				
	8	75	1.557	28	1.472				
	9	75	1.472	21	1.303				
4620A2	10	74	0.595	12	0.595				
	11	74	0.453	16	0.510				
	12	74	0.396	14	0.340				
	1	75	0.283	25	0.425				
	2	75	0.255	15	0.227				
	3	75	0.396	15	0.453				
	4	75	2.520	12	1.529				
	5	75	3.398	29	2.152				
	6	75	2.180	16	1.784				
	7	75	1.246	12	1.274				
	8	75	0.680	28	0.566				
	9	75	0.736	21	0.850				
4620ZZ	10	74	0.0						
	11	74	0.0						
	12	74	0.0						
	1	75	0.0						
	2	75	0.0						
	3	75	0.0						
	4	75	0.003						
	5	75	0.014						
	6	75	0.008						
	7	75	0.003						
	8	75	0.0						
	9	75	0.0						

APPENDIX D

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 76/05/03

462001
44 04 13.0 103 29 27.0 3
PACTOLA RESERVOIR
46103 SOUTH DAKOTA
090491

11EPALES 2111202
0139 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
74/04/25	08 30	0000	6.6		288	230		147	0.020	0.200	0.040	0.005
	08 30	0005	6.5	10.2		230		147	0.030	0.200K	0.040	0.002
	08 30	0030	6.4	10.4		229		146	0.020	0.200K	0.030	0.002
	08 30	0060	5.6	8.6		223		147	0.020	0.200K	0.030	0.002K
	08 30	0100	5.1	10.2		221		147	0.030	0.200K	0.040	0.002K
	08 30	0130	5.0	10.4		220		147	0.040	0.300	0.060	0.009
74/07/15	11 55	0000	21.2	7.4	300	350	8.40	160	0.070	0.500	0.080	0.055
	11 55	0005	21.2	7.2		350	8.50	160	0.060	0.200	0.070	0.067
	11 55	0015	21.1	7.4		350	8.50	159	0.030	0.200K	0.030	0.072
	11 55	0035	14.2	9.2		295	8.60	165	0.040	0.200K	0.020	0.051
	11 55	0060	9.1	8.8		266	8.40	160	0.040	0.200K	0.030	0.036
	11 55	0090	7.1	8.0		254	8.30	164	0.060	0.200K	0.060	0.046
	11 55	0125	6.0	7.0		250	8.00	167	0.100	0.200K	0.090	0.060
74/09/12	12 30	0000	16.2	8.0	340	287	8.05	157	0.030	0.300	0.020K	0.003
	12 30	0005	16.2	8.0		290	8.15	156	0.020	0.200K	0.020K	0.007
	12 30	0030	16.2	8.2		288	8.10	157	0.020	0.200K	0.020K	0.006
	12 30	0045	16.0	8.0		285	8.08	158	0.040	0.200K	0.020K	0.005
	12 30	0055	11.7	7.2		254	7.79	158	0.030	0.200K	0.020K	0.006
	12 30	0060	10.8	7.8		248	7.80	157	0.030	0.200K	0.020K	0.008
	12 30	0070	9.7	7.6		239	7.75	159	0.030	0.200K	0.060	0.006
	12 30	0090	8.5	7.0		233	7.68	162	0.020	0.200	0.040	0.007
	12 30	0121	7.3	4.0		230	7.45	164	0.040	0.500	0.140	0.008

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/05/03

462001
44 04 13.0 103 29 27.0 3
PACTOLA RESERVOIR
46103 SOUTH DAKOTA
090491

11EPALES 2111202
0139 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
74/04/25	08 30	0000	0.010	2.2	
	08 30	0005	0.009		
	08 30	0030	0.009		
	08 30	0060	0.009		
	08 30	0100	0.008		
	08 30	0130	0.010		
74/07/15	11 55	0000	0.054	2.0	
	11 55	0005	0.071		
	11 55	0006			50.0
	11 55	0015	0.065		
	11 55	0035	0.064		
	11 55	0060	0.068		1.0
	11 55	0090	0.065		
	11 55	0125	0.060		
74/09/12	12 30	0000	0.009	0.6	
	12 30	0005	0.015		
	12 30	0030	0.012		
	12 30	0045	0.009		
	12 30	0055	0.011		
	12 30	0060	0.012		
	12 30	0070	0.011		
	12 30	0090	0.009		
	12 30	0121	0.012		

26

STORET RETRIEVAL DATE 76/05/03

462002
44 04 28.0 103 30 40.0 3
PACTOLA RESERVOIR
46103 SOUTH DAKOTA
090491

11EPALES 2111202
0085 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
74/04/25	09 00	0000	6.8		312	232		148	0.020	0.200K	0.040	0.005
	09 00	0005	6.8	10.4		230		149	0.030	0.200K	0.060	0.005
	09 00	0030	6.2	10.4		229		149	0.020	0.200	0.040	0.004
	09 00	0060	5.1	10.0		220		147	0.040	0.200K	0.060	0.004
	09 00	0080	5.0	9.8		220		149	0.020	0.200K	0.050	0.003
74/07/15	12 30	0000	21.7	7.0	288	358	8.40	161	0.060	0.500	0.070	0.048
	12 30	0005	21.4	7.6		356	8.30	158	0.040	0.200K	0.050	0.042
	12 30	0015	20.8	7.4		350	8.30	159	0.050	0.200K	0.060	0.059
	12 30	0030	16.7	8.0		324	8.20	162	0.040	0.200K	0.050	
	12 30	0043	10.8	8.8		283	8.10	147	0.040	0.200K	0.030	0.007
	12 30	0070	8.2	7.2		263	8.00	123	0.060	0.200K	0.030	0.003
74/09/12	13 25	0000	16.3	8.0	340	293	8.15	164	0.020K	0.400	0.020	0.004
	13 25	0005	16.3	7.8		295	8.20	165	0.020K	0.200K	0.020	0.007
	13 25	0015	16.3	8.0		292	8.17	165	0.020K	0.200K	0.020K	0.006
	13 25	0030	16.3	8.0		292	8.14	166	0.020K	0.200K	0.020K	0.006
	13 25	0045	15.5	7.0		295	7.98	173	0.020K	0.200K	0.020K	0.005
	13 25	0055	11.9	5.4		263	7.61	173	0.020	0.200K	0.040	0.009
	13 25	0063	10.0	5.2		252	7.59	173	0.020K	0.200K	0.050	0.007

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/05/03

462002
44 04 28.0 103 30 40.0 3
PACTOLA RESERVOIR
46103 SOUTH DAKOTA
090491

11EPALES 2111202
0085 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
74/04/25	09 00	0000	0.010	1.9	
	09 00	0005	0.008		
	09 00	0030	0.009		
	09 00	0060	0.008		1.0
	09 00	0080	0.007		
74/07/15	12 30	0000	0.050	1.3	
	12 30	0003			50.0
	12 30	0005	0.082		
	12 30	0015	0.066		
	12 30	0030	0.056		
	12 30	0043	0.059		1.0
	12 30	0070	0.064		
74/09/12	13 25	0000	0.009	0.6	
	13 25	0005	0.008		
	13 25	0015	0.008		
	13 25	0030	0.007		
	13 25	0045	0.011		
	13 25	0055	0.009		
	13 25	0063	0.009		

STORET RETRIEVAL DATE 76/05/03

462003
44 34 52.0 103 32 28.0 3
PACTOLA RESERVOIR
46103 SOUTH DAKOTA
090491

11EPALES 2111202
0030 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
74/04/25	09 40	0000	8.0		108	250		166	0.040	0.200	0.110	0.010
	09 40	0005	7.6	10.2		242		155	0.040	0.200K	0.090	0.005
	09 40	0015	6.8	10.2		240		153	0.020	0.200K	0.050	0.004
	09 40	0025	6.4	9.8		240		157	0.030	0.300	0.070	0.007
74/07/15	13 05	0000	22.0	7.4	156	365	8.30	159	0.050	0.200	0.060	0.038
	13 05	0005	21.7	7.6		362	8.30	157	0.040	0.200K	0.070	
	13 05	0010	21.3	7.0		363	8.20	162	0.030	0.200K	0.050	0.055
	13 05	0016	20.6	6.4		373	8.10	167	0.060	0.200K	0.070	0.052
74/09/12	14 00	0000	16.0	8.6	132	293	8.19	174	0.020K	0.200K	0.020K	0.002
	14 00	0005	15.8	8.4		295	8.25	175	0.020K	0.500	0.020K	0.006
	14 00	0010	15.4	8.4		293	8.25	176	0.020K	0.200K	0.020K	0.006
	14 00	0017	11.3	9.0		281	8.29	194	0.020	0.200K	0.020K	0.004

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
74/04/25	09 40	0000	0.015	1.9	
	09 40	0005	0.011		
	09 40	0015	0.011		
	09 40	0025	0.059		1.0
74/07/15	13 05	0000	0.055	2.2	
	13 05	0001			50.0
	13 05	0005	0.060		
	13 05	0010	0.056		
	13 05	0016	0.059		
	13 05	0020			1.0
74/09/12	14 00	0000	0.007	0.6	
	14 00	0005	0.010		
	14 00	0010	0.010		
	14 00	0017	0.020		

K VALUE KNOWN TO BE
LESS THAN INDICATED

APPENDIX E

TRIBUTARY DATA

STORET RETRIEVAL DATE 76/05/04

462CA1
44 04 36.0 103 28 54.0 4
RAPID CREEK
46 7.5 PACTOLA DAM
O/PACTOLA RESERVOIR 090491
BRDG ON DIRT RD .2 MI BELOW PACTOLA DAM
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/10/12	10 30		0.096	0.300	0.040	0.010	0.010
74/11/16	09 55		0.024	0.700	0.100	0.005	0.005
74/12/14	13 00		0.016	0.700		0.005	0.010K
75/01/25	09 00		0.040	0.600	0.032	0.008K	0.010K
75/03/15	12 20		0.064	0.400	0.056	0.008K	0.010
75/04/12	12 00		0.040	0.950	0.040	0.010	0.010
75/05/29	11 30		0.030	0.350	0.035	0.005K	0.010K
75/06/16	09 00		0.025	0.600	0.040	0.005K	0.020

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/05/04

4620A2
44 05 15.0 103 34 20.0 4
RAPID CREEK
46 7.5 SILVER CITY
T/PACTOLA RESERVOIR 090491
BRDG ON LHT DTY RD .7 M NW OF SILVER CTY
11EPALES 211120
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/10/12	11 00		0.016	0.200	0.015	0.005	0.065
74/12/14	12 20		0.072	0.600	0.010	0.005	0.010K
75/01/25	09 30		0.112	0.400	0.024	0.008K	0.010K
75/03/15	12 45		0.120	0.600	0.024	0.008K	0.020
75/04/12	12 25		0.140	0.700	0.010	0.010	0.030
75/05/29	10 00		0.045	0.850	0.025	0.005	0.150
75/06/16	10 00		0.035	1.250	0.015	0.005	0.160

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/05/04

4620C1
44 05 10.0 103 48 00.0 4
N FORK CASTLE CREEK
46 7.5 DEERFIELD
T/PACTOLA RESERVOIR 090491
SEC RD BRDG JUST NE OF REYNOLDS RANCH
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/10/12	12 05		0.008	0.300	0.010	0.005K	0.025
74/11/09	12 30		0.024	0.200	0.025	0.010	0.010
74/12/07	09 10		0.056	0.500	0.005	0.005K	0.030
75/01/18	09 15		0.088	0.900	0.016	0.008K	
75/02/09	13 30		0.096	0.450	0.032	0.008K	0.025
75/03/15	10 20		0.092	0.200	0.016	0.008K	0.030
75/04/12			0.330	0.700	0.025	0.010	0.030
75/04/30	19 45		0.300	0.450	0.085	0.020	0.050
75/05/16	15 25		0.105	0.300	0.020	0.010	0.030
75/06/04	14 00		0.035	0.700	0.015	0.005K	0.020
75/06/15	11 00		0.010	0.800	0.005K	0.005	0.040
75/07/12	14 10		0.020	0.350	0.030	0.010	0.030
75/08/28	18 55		0.010	0.750	0.015	0.005	0.050
75/09/21			0.020	0.800	0.005	0.005K	0.030

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/05/04

462001
44 07 25.0 103 41 50.0 4
SILVER CREEK
46 7.5 ROCHFORD
T/PACTOLA RESERVOIR 090491
SEC RD XING 1.2 MI E OF ROCHFORD
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/10/12	12 05		0.096	0.200	0.010	0.005K	0.005
74/11/16	10 50		0.128	0.100	0.025	0.005K	0.005K
74/12/14	14 45		0.128	0.400	0.020	0.005K	0.010K
75/01/25	10 45		0.144	0.100	0.008	0.008K	0.010K
75/03/15	13 45		0.204	0.325	0.016	0.008K	0.030
75/04/12	13 35		0.195	1.100	0.015	0.005	0.010
75/05/29	11 00		0.070	0.150	0.015	0.005K	0.010
75/06/16	11 00		0.075	0.200	0.005	0.005K	0.020

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/05/04

4620E1
44 06 25.0 103 38 40.0 4
GIMLET CREEK
46 7.5 ROCHFORD
T/PACTOLA RESERVOIR 090491
SEC RD XING 5 MI ESE OF ROCHFORD
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
75/04/12	14	08	0.240	0.800	0.060	0.020	0.040
75/05/29	12	00	0.010	0.100	0.015	0.010	0.010
75/06/16	12	00	0.005	0.400	0.020	0.015	0.015

STORET RETRIEVAL DATE 76/05/04

4620F1
44 00 15.0 103 42 25.0 4
SLATE CREEK
46 7.5 ROCHFORD
T/PACTOLA RESERVOIR 090491
SEC RD BRDG .7 MI E OF SLATE PRAIRIE CHR
11EPALES 211120
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/10/12	11	15	0.024	0.250	0.015	0.010	0.020
74/11/09	12	00	0.032	0.400	0.025	0.020	0.020
74/12/07	08	05	0.064	0.800	0.017	0.010	0.020
75/04/30	18	25	0.345	0.450	0.050	0.035	0.060
75/05/16	15	00	0.010	0.500	0.030	0.010	0.020
75/06/04	13	00	0.015	0.550	0.025	0.010	0.040
75/06/15	10	30	0.010	0.450	0.020	0.020	0.040
75/07/12	13	25	0.005	0.400	0.015	0.020	0.030
75/08/28	17	15	0.015	0.250	0.010	0.010	0.010
75/09/21			0.015	0.400	0.005	0.005K	0.060

K VALUE KNOWN TO BE
LESS THAN INDICATED